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Some Notes on Statistics of SWATHs and Catamarans

Victor Dubrovsky

Balt Techno Prom Ltd, St. Petersburg, Russian Federation

Email address:
multi-hulls@yandex.ru

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Abstract: More or less researched types of multi-hull ships and their specificities: the general view. The main conformity of the ship types and theirs technical and exploitation characteristics. Twin-hulls as most wide- spread types of multi-hulls, especially as high-speed passenger ones. Ship performance as the most important characteristic of fast enough ships. The main dimensions and general characteristics of 25 built twin-hull ships with small water-plane area and 15 built high-speed catamarans. (It is not so big volume for statistics, but even it allows showing of some useful characteristics of these ships.) Some important characteristics of these ships were examined: so named "admiral coefficient; relative speed (Froude number by a hull length); relative length of a hull; relative draft". Calculated relative characteristics show, firstly, evident growth of admiral coefficient of SWATHs with Froude number increasing. Surprisingly, the examined high-speed catamarans have slightly lower admiral coefficient at corresponded Froude numbers, most possible because of smaller immersion of the main volume of hulls and smaller draft, which defines smaller diameter of propulsors. Relative length and relative draft of SWATHs show moderate growth for bigger Froude numbers, but the dispersions are big enough and the usable numbers of these characteristics are not defined more or less exactly. But the better (from propulsion point of view) shown ships can be applied for approximate estimation of the same characteristic of newly designed ships.

Keywords: Multi-hulls, Admiral Coefficient, SWATH, Catamaran, Statistics, Relative Dimensions, Relative Draft, Relative Length

1. Introduction

General view on multi-hulls. Twin-hull ships as a separate ship type were used periodically since Ancient ages.

For example the first combat steamship was the catamaran "Demologos", Figure 1.

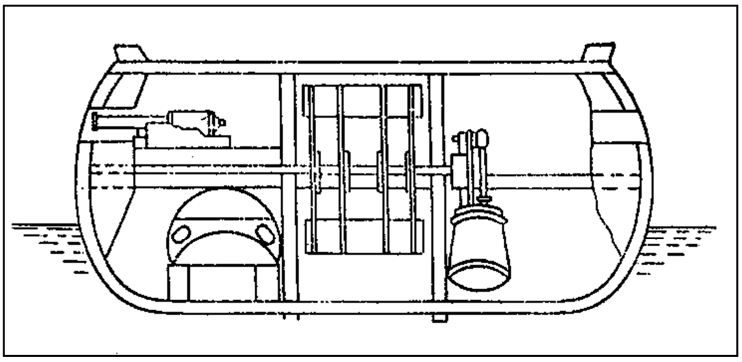

Figure 1. *Cross section of the first combat steam ship-catamaran "Demologos" [1].*

Most wide application of catamarans of various purposes and wide enough researching of them and of the other multi-hulls began after the World War II. Most wide and detail description of the process is shown by the books [2-5].

Today some types of various multi-hulls are researched enough for concept designing without any additional model tests and mass calculations, [6].

Figure 2 shows the researched types of multi-hulls of usual shape of hulls.

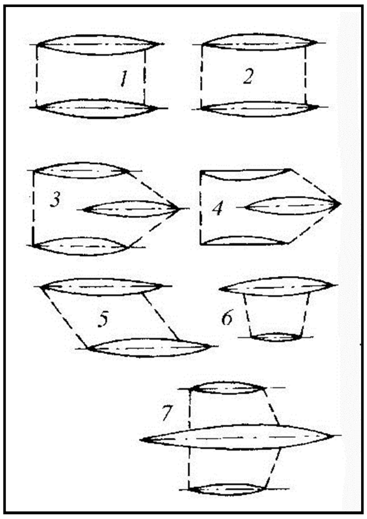

Figure 2. *The examined types of usually-shaped multi-hulls.*

1, 2 – the catamarans with symmetrical and unsymmetrical hulls (the biggest transverse stability); 3,4 – the same trimarans (in Russian terminology), the biggest interaction of wave systems; 5 – a catamaran with shifted hulls (a sum of characteristics of a catamaran and a trimaran); 6 – proa (the minimal mass of the transverse structure); 7 – an outrigger ship (small enough mass of transverse structure).

Figure 3 contains some types of ships with small water-plane area (SWA ships).

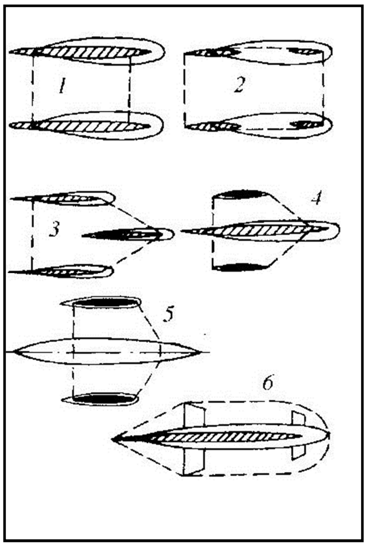

Figure 3. *The examined ships with small water-plane area.*

1 – a duplus (twin-hull ship with one long strut on each under-water volume, "gondola"), maximal transverse stability of SWA ships; 2 – a trisec (twin-hull ship, two short struts on each gondola) minimal area of water-plane; 3 – a tricore (triple-hull ship of small water-plane area), maximal interaction of wave systems of SWA ships; 4 – an outrigger SWA ship, small enough mass of the transverse structure; 5- a ship with usual main hull and SWA outriggers (option of S. Rudenko); 6 – foiled mono-hull SWA ship, for higher achievable speeds.

Thousands of small-sized catamarans are applied as passenger, tourist, pleasure, and fishery roles;

1. Hundreds of catamarans as fast passenger and car-passenger ferries (today about 70% of these ferries are catamarans), for example [7];
2. Some catamarans as auxiliary, service, crane ships (for example, [8];
3. Hundreds of semi-submersible rigs for various purposes (for example, [9]);
4. Dozens of small water-plane area ships for full-scale tests and for practical applications, twin-hulls in main, for example, [10-12]);
5. A number of ships with one or two outriggers, including a record sail racer (for example, [13]).

The characteristics of the multi-hulls in use today are briefly examined below.

The relatively larger area of their decks, elimination of the transverse stability problem, reduced roll, the major provision of non-sinkability, and the large aspect ratio of the hulls, all ensure the effective application of catamarans as fast passenger and car-passenger ferries.

Today the special shape of the bow parts of the hulls and the above-water platform ensures the highest level of seakeeping in head waves in the so-called "wave-piercing" catamarans (WPC). Such catamarans are the most effective ferries in terms of contemporary capacity and speed, [14]. Most new multi-hull type is SWATH ("small water-plane area twin hull"). A lot of theoretical, full-scale and experimental data shows that the seaworthiness of a SWATH is approximately the same as that of a mono-hull with a bigger (5-15 times greater) displacement.

The other specificities of SWA ships are the same as those of other multi-hulls: increased area of decks, large volume of the above-water platform, lack of transverse stability problems.

The simple modernization of any mono-hull by adding one or two outriggers allows a substantial increase of capacity (on the decks) and transverse stability, i.e., greater safety of ships employed for various purposes, such as passenger transport or fishery. This modernization can be carried out even without docking the initial ship.

The building of an outrigger battleship is the next important stage of naval fleet development. Such a ship differs from a comparable mono-hull in having a larger area upper deck, greater transverse stability, a larger aspect ratio of the main hull (with the usual shape), and smaller pitch at moderate speeds.

Semi-submersible rigs, as floating objects with a small water-plane area, consist of two or three underwater pontoons that are connected with the above-water platform by a number of struts built in rectangular or circular sections (columns). The design draft is placed at about half of the column height, while the transport draft is placed near the top of the pontoons. Such rigs guarantee all-weather exploitation even in the worst wave and wind conditions.

A separate line of multi-hull development today is researching and building high-speed ships with a small water-plane area and twin hulls (SWATH - "ship with small water-plane, twin hull"). A lot of theoretical, full-scale and experimental data shows that the seaworthiness of a SWATH is approximately the same as that of a mono-hull with a bigger (5-15 times greater) displacement.

The other specificities of SWA ships are the same as those of other multi-hulls: increased area of decks, large volume of the above-water lack.

2. Some Notes on High-speed SWATHs Versus Catamarans

Evidently, good enough performance is the key characteristic of any high-speed vessels. But good performance must be ensured by the selection of some correlations of dimensions. Some statistical data are examined below.

The book [15] contains the main dimensions and general characteristics of 25 built twin-hull ships with small water-plane area (SWA ships) and 28 built high-speed catamarans. It is not so big volume for statistics, but even the information allows showing some useful characteristics of these ships.

The examined characteristics are:

1. Froude number by a hull length $Fn = 0{,}515v_S/(L*g)^{1/2}$, here L – hull length, m, g = 9,81 m/sec^2;
2. Relative length of a hull $l_1 = L/W_1^{1/3}$, here W_1 – a hull volume displacement, cu m;
3. Relative draft $d_2 = d/W_1^{1/3}$;
4. "Admiral coefficient" $C_2 = D^{1/3}v_S/P$, here D – full displacement, t, v_S – speed, knots, P – main engine power, kWt.
5. Relative length as the characteristic of a hull lengthening, as usually, shows the correlation of wave and viscous resistance of a ship.

Bigger draft means bigger immersion of the hull volume and bigger possible diameter of propulsors, i.e. higher propulsive coefficient.

Admiral coefficient shows the total effect of design solutions for performance.

3. Some Built SWATHs

Some relative dimensions and characteristics are based on the initial table of the book, see Table 1.

Table 1. *Some characteristics of built 25 SWATH.*

#	Ship name	Displa - cement, t	Length, m	Speed. Kn	Power, kWt	Adm. Coeffic.	Froude Numb.	Rel. Length	Rel. draft
1	"Kaimalino"	193	26.8	25	3132	222.3	0.79	5.84	1.16
2	"Marine Ace-1"	18.4	12.3	17.3	298	161.9	0.66	5.87	0.74
3	"Marine Ace-1a"	22.2	12.35	15.4	298	129.4	0.72	5.53	0.69
4	"Seagull"	338	35.9	27.1	6040	213.3	0.74	6.49	0.57
5	"Kotozaki"	236	27	20.5	2834	154.9	0.64	5.5	0.65
6	"Ohtori"	239	27	20.6	2834	158.5	0.647	5.48	0.69
7	Ex "Suave Lino"	40	19.2	18	632	144.2	0.674	7.07	0.78
8	"Charwin"	193	25.3	10	485	91.9	0.35	5.51	0.6
9	"Kaiyo"	2849	61.55	14.1	7400	101.4	0.29	5.47	0.56
10	"Halcyon"	52	18.3	20	761	195.6	0.768	5.1	0.72
11	"Marine Wave"	19	15.1	18	373	148.8	0.768	7.1	0.75
12	"Sun Marina"	19	15.05	20.5	447	183.4	0.867	7.1	0.75
13	"Chubasco"	76	21.95	20	1119	171.3	0.701	10.97	0.9
14	"Frederick G. Creed"	80.26	20.4	25	1610	241	0.909	5.96	0.76
15	T-AGOS-19	3450	71.3	10.4	3341	102	0.202	5.95	0.63
16	"Bay Queen"	40	18	20	1266	98.73	0.774	6.6	0.59
17	"Seagull-2"	350	39.3	30	7882	226.9	0.786	7.03	0.58
18	FCS 400 "Patria"	180	36.5	30	4022	285	0.816	8.14	0.61
19	"Aegian Queen", design	1060	51.5	30	14914	250	0.69	6.36	0.62
20	"Navatek-1"	365	40.24	17.5	1912	191	0.45	7.09	0.65
21	"2000 Class"	80	20.43	25	1610	240.6	0.91	5.97	0.76
22	"Hibiki"	3700	67.0	11	2386	177.6	0.22	5.45	0.62
23	'T-AGOS-23"	5368	85.78	12	3710	102	0.31	5.6	0.57
24	"Radisson Diamond"	12000	131.2	14.15	11345	174.2	0.203	7.22	0.42
25	"Customs 201"	228	35	17.5	2240	119.5	0.486	7.2	0.58

4. Some Built Catamarans

Unfortunately, there are the needed data on main dimensions and general characteristics of 15 catamarans only, see Table 2.

Table 2. *Some characteristics of built 15 catamarans.*

#	Type or name of craft	Displa - cement, t	Length, m	Speed. Kn	Power, kWt	Adm. Coeffic.	Froude Numb.	Rel. Length	Rel. draft
1	W86	54	22.7	26	1618	114	0.966	7.6	0.31
2	W95	74	29.3	31	2646	146	0.973	5.87	0.33

#	Type or name of craft	Displa - cement, t	Length, m	Speed. Kn	Power, kWt	Adm. Coeffic.	Froude Numb.	Rel. Length	Rel. draft
3	W100	84	31.7	26	2646	94	0.817	9.1	0.39
4	W3700SC	120	36.5	32	4080	144	0.952	9.3	0.30
5	20m	48	18.5	24	735	182	0.87	6.4	0.41
6	21m	48	19.5	25	1103	137	0.88	6.76	0.44
7	22m	55	19.5	25	1176	141	1.08	6.46	0.45
8	26m	82	23.5	31	1970	135	0.95	6.8	0.51
9	29m	93	25.5	26	1764	150	0.79	7.1	0.39
10	“Johnson”	21	13.4	16.4	549	71	0.73	6.1	-
11	“Shuman”	36.3	18.3	24.2	1020	178	0.93	6.96	0.25
12	“Double eagle”	29.5	19.8	21.2	240	166	0.82	7.46	0.26
13	“Double eagle II”	28.4	19.8	23.4	800	174	0.91	7.36	0.23
14	“Rainbow II”	37.5	18.9	20.8	800	147	0.79	7.1	0.28
15	“H&M Speed Two”	40.9	18.3	24	800	120	0.77	6.7	0.27

5. Relative Dimensions Versus Froude Number

As usually, bigger relative length of a hull ($l = L/V_1^{1/3}$) means smaller wave resistance and bigger wetted area, i.e. bigger viscous resistance. Figure 4 contains the dependence of the relative length from Froude number by the length of a hull.

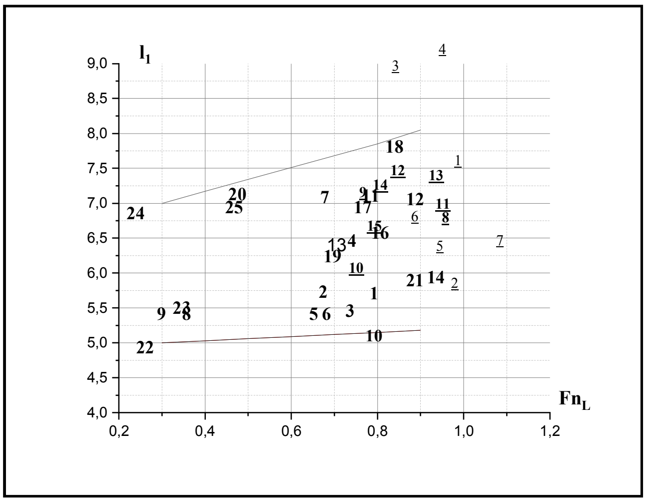

Figure 4. Relative length of a hull $l = L/V_1^{1/3}$ vs. Froude number by a hull length FnL (upper and lower values of SWATHs are approximately shown by lines, not marked numbers correspond to Table 1, italic numbers correspond to catamaran data).

Evidently, the dispersion of the points is big enough, than a definite trend is not notable. But in main the relative length slightly growths for bigger Froude numbers.

Evidently, the examined catamarans have approximately the same relative length of a hull.

Bigger relative draft means bigger immersion of the main displaced volume of small water-plane hull, and, therefore, smaller wave resistance, but bigger wetted area, i.e. bigger viscous resistance. Besides, bigger draft means the possibility of bigger diameter of propellers, i.e. higher propulsive coefficient usually.

The Figure 5 shows the comparison of relative draft of the examined ships $d/V_1^{1/3}$ versus Froude number.

Evidently, the dispersion is big enough, but small trend of growth for bigger Froude numbers can be noted. And the values of catamaran hull relative draft are evidently lower ones, than of SWA ships.

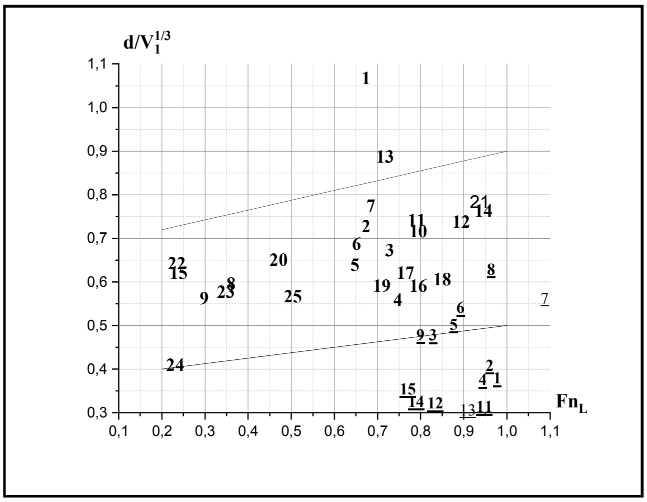

Figure 5. Relative draft $d/V_1^{1/3}$ versus Froude number Fn_L (upper and lower values of SWATHs shown approximately by lines, usual numbers correspond to Table 1, italic ones – to Table 2).

6. Performance Characteristic

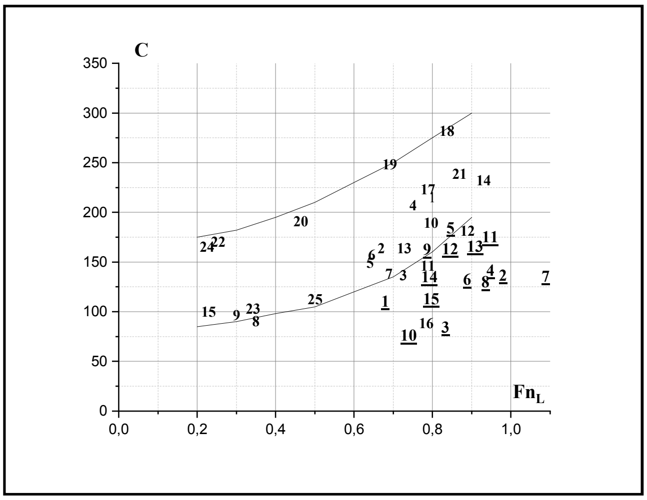

Figure 6. Admiral coefficient $C = W^{2/3}v_S^3/P$ vs. Froude number (the biggest and smallest values of SWATHs are shown by lines, usual numbers correspond to Table 1, underlined ones – to Table 2).

So named "admiral coefficient" C, see previously definitions, is one from possible characteristic of a ship performance. Figure 6 contains such coefficient versus Froude number by length Fn.

In spite of big enough dispersion, growth of C of SWA ships with Froude number growth seems evident. It is a very interesting fact, because corresponded coefficient of traditional mono-hulls drops with growth of Froude number by hull length.

7. Discussion

The values of admiral coefficient of the examined catamarans in general are smaller, than of SWA ships. It can be supposed, it is the main result of bigger immersion of the main displaced volume of SWA ships and bigger diameter of theirs propulsors.

8. Conclusions

i. Relative length of the examined SWATHs and catamarans can be approximately the same.
ii. Relative drafts of the examined catamarans are in main smaller, than of the examined SWATHs.
iii. Admiral coefficient of the examined SWATHs is bigger, than of the examined catamarans, especially at high enough Froude numbers.

9. Recommendation

The shown dependencies can be applied for early stages of performance estimation of the twin-hull ships with small water-plane area and high-speed catamarans.

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